Report 76-0037

An Experimental Investigation of Babbitt Metal Bonding

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AN EXPERIMENTAL INVESTIGATION OF BABBITT METAL BONDING

by
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MATERIALS DEPARTMENT
Annapolis
RESEARCH AND DEVELOPMENT REPORT

May 1976

Report 76-0037

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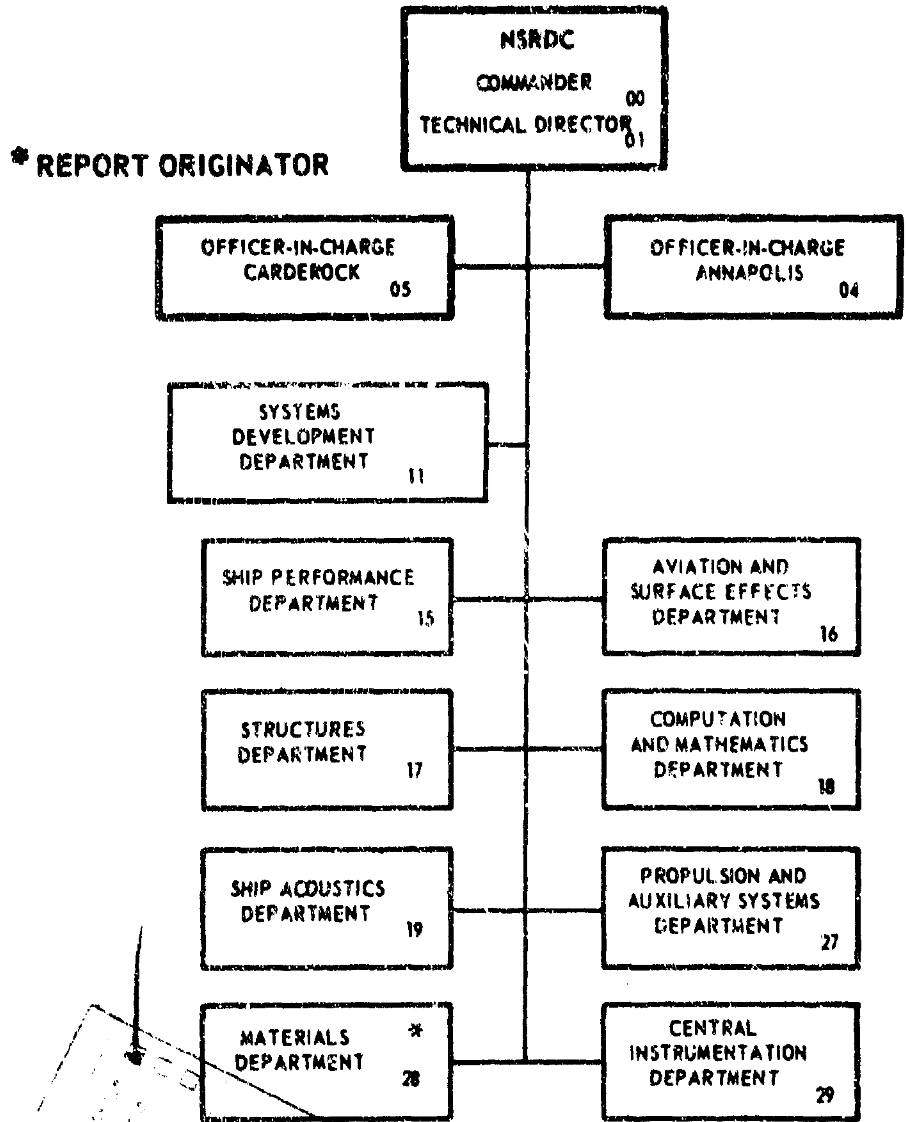

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 76-0037

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

9

4. TITLE (and Subtitle)

6 AN EXPERIMENTAL INVESTIGATION OF BABBITT METAL BONDING.

5. TYPE OF REPORT & PERIOD COVERED

Research ~~&~~ and Development rept.,

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

10 Michael G. Vassilaros

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

David W. Taylor Naval Ship R&D Center
Annapolis, Maryland 21402.

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

Task Area ZF 61512001
~~Element 62766N~~
Work Unit 2814-170

11. CONTROLLING OFFICE NAME AND ADDRESS

David W. Taylor Naval Ship R&D Center
Bethesda, Maryland 20084

11

12. REPORT DATE: May 1976

13. NUMBER OF PAGES: 17

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

12 18p.

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

14 DTNSRDC-76-0037

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

16 ZF61-512

18. SUPPLEMENTARY NOTES

17 ZF61-512-001

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Babbitt metal
Bearings
Tinning
Bond strength
Casting

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Several methods of casting babbitt metal to steel were evaluated for bond strength by use of tensile-type specimens. The methods investigated were the use of a tin bath, torch/tin stick, and electroplated nickel to insure proper babbitt-to-steel bond, as well as no tinning. Of the methods performed, only the tin-bath method consistently produced a bond stronger than the babbitt

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S/N 0102-014-6601

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

387 682

20. Abstract (cont)

metal itself. The bond strengths developed in the other methods tested were erratic and always less than that obtained with the tin-bath method. The torch/tin stick method gave an adequate compromise between bond strength and convenient application. It was found that the oxide formed on the tinned surface which precludes good bonding could be effectively removed by the use of flux during babbitt casting.

(Author)

ADMINISTRATIVE INFORMATION

This report was prepared under Task Area ZF 61512001, Element Number 62766 N on Investigation of Babbitt Metal Bonding, Work Unit 1-2814-170. The investigation was sponsored by NAVMAT (MAT 0314) as part of the IR/IED program of the Center under the direction of Dr. A Powell (Code 01).

ACKNOWLEDGMENT

The author wishes to express his grateful appreciation for the assistance and guidance given by Mr. Robert F. Gustafson (Code 2784) throughout the project.

LIST OF ABBREVIATIONS

° C - degrees Celsuis
° F - degrees Fahrenheit
m - meter
mm - millimeter
MPa - Megapascals
psi - pounds per square inch

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

The Navy's extensive use of babbitt bearings in surface ship machinery requires that Navy tenders and repair ships have the capability of repairing babbitt metal bearings on board. The practice of casting babbitt within the limited facilities of a tender's foundry has evolved over years to a "traditional" procedure passed on by crew chiefs. This method is simpler than the bearing manufacture's methods[1,2] which are designed to optimize bearing strength, and require a large, well-equipped facility. In present tender practice, the babbitt lining of a bearing is bonded to the steel or bronze bearing shell by means of a tin interface layer. Normally, the tin is applied to the hot bearing shell, after which the shell is set up in a mold and molten babbitt poured in.

The primary difference in the methods is the way in which the tin interface layer is applied. Manufacturers are able to use a bath of molten tin in which the hot bearing shell is immersed; however, aboard ship the shell is heated by a flame torch, and a stick of tin is melted on the shell, much as solder is applied to connections. The hot tin layer oxidizes rapidly, while cooling, and the subsequent bond is often weak and brittle. Many turbine, gear, and lineshaft bearings are renewed annually because of poor bonding. Furthermore, rebabbitting bearings frequently requires excessive man-hours of work because of the unsatisfactory bonding and consequent rework.

The traditional method, as well as modifications, and alternatives to this method were investigated to develop and recommend a simple, improved method of bonding babbitt bearing linings to metallic bearing shells. The investigation intended to characterize the important features of a simple babbitt-bonding procedure for possible use in a tender's foundry. Various babbitt-bonding procedures were used to make tensile specimens of steel bonded to babbitt. The breaking strength of these specimens was used to evaluate the relative efficiency of several bonding methods, as compared to the standard method of using a tin bath for applying the tin interface layer.

Means of improving the torch/tin stick method as well as methods to eliminate tinning, and electroplating methods were studied.

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[1] Superscripts refer to similarly numbered entries in the Technical References at the end of the text.

MATERIALS

The babbitt metal used was a tin-based babbitt alloy number 2 (Navy designation). The alloy is commercially available under a variety of trade names all with a nominal composition of 7%-8% antimony, 3%-4% copper, and the remainder tine (88% minimum). Commercially pure tin metal was used in the tinning processes. The flux, when employed, was a standard solution of zinc chloride made from zinc metal dissolved in concentrated hydrochloric acid. Low carbon steel bars (AISI 1C15), 1/2 inch x 1/2 inch x 20 feet (12.7 m x 12.7 mm x 6.096 m),* were used as the base metal to which the babbitt was bonded.

DESCRIPTION OF EQUIPMENT

The babbitt was cast into a stainless steel fixture (figure 1) which held the steel bars in a gapped position during casting, so that the steel bars and the fixture when assembled formed the mold. A stainless steel crucible in a pot of molten lead held the tin bath. When torch tinning was performed, an oxy-acetylene torch adjusted to give a reducing flame was used to heat the assembly, and the tin was applied with a tin stick, a long thin bar of tin metal. The flux solution was applied directly with a flux brush, i.e., no flux-cored sticks were used.

METHOD OF TEST

The strength of the babbitt-to-steel bond was measured using a tensile specimen composed of the two 1/2-inch square (12.7 mm) steel bars whose ends were joined in a slug of cast babbitt approximately 3/4 inch (19.05 mm) long and 1/2 inch (12.7 mm) square. The specimens were pulled in a universal testing machine which recorded the maximum load to failure. The maximum stress was calculated from the maximum load and the cross-sectional area of the fracture.

BONDING METHODS

Five different babbitt-to-steel bonding methods were investigated, and these are described briefly in the following.

*A list of abbreviations used appears on page i.

Method I - Standard Method (Tin Bath)

This method simulated the recommended procedure for achieving a strong babbitt metal-to-steel bond, and is used in the manufacture of new babbitt bearings. The steps performed were as follows:

- Sand the steel surface (smooth) to remove rust.
- Degrease the steel surface with acetone.
- Flux the steel with a solution of ZnCl.
- Hold in a tin bath for 1 minute at 700° F (371° C).
- Insert tinned steel blanks into stainless steel fixture and preheat in furnace.
- Cast liquid babbitt into mold cavity.
- Stir molten babbitt and cool mold with flowing water.

Method II - Torch Tinning

This method simulated present Navy tender foundry practices. The characteristic feature of this method was the use of a heating torch/tin stick instead of a tin bath. The steps were as follows:

- Sand and degrease the steel bars with acetone.
- Heat the steel with an oxy-acetylene torch while applying ZnCl solution and tin from a tin stick.
- Insert tinned blanks into casting fixture.
- Preheat fixture assembly.
- Cast liquid babbitt into mold cavity.
- Stir molten babbitt and cool mold with flowing water.

Method III - No Tinning

This method simulated a bonding method which eliminated the tinning steps to find if flux alone might give adequate bonding. The steps are listed below:

- Sand and degrease the steel bars with acetone.
- Place cleaned steel blank into casting fixture.

* Preheat fixture assembly.

* Pour flux into fixture just prior to casting.

* Cast liquid babbitt into mold cavity.

* Stir molten babbitt and cool with flowing water.

Method IV - Electroplated Nickel

This method incorporated a substitute for tinning, wherein a portable electroplating rig was used to electroplate nickel onto the steel, instead of tinning the surface with molten metal. The method was as follows:

* Sand and degrease the steel bars with acetone.

* Electroplate nickel with commercially available plating kit.[3]

* Insert plated steel blanks into the cast fixture.

* Preheat fixture assembly.

* Pour flux into mold just prior to casting.

* Cast liquid babbitt into mold cavity.

* Stir molten babbitt and cool with water.

Method V - Rebabbitting

This method simulated the rebabbitting of previously cast bearings to determine whether the tinning or nickel plating could be reused by melting off the old babbitt and recasting new babbitt.

* Melt off babbitt from previously babbitted specimens.

* Insert the steel blanks into casting fixture.

* Preheat fixture assembly.

* Pour flux into mold just prior to casting.

* Cast liquid babbitt into mold cavity.

* Stir molten babbitt and cool with flowing water.

It has been found[1] that a tin-bath temperature of 660° F (349° C) to 930° F (499° C) is necessary for good tinning of steel; accordingly, a temperature of 700° F (371° C) was chosen as the tin-bath temperature used for method I.

The babbitt temperature in the ladle at pouring was 700° F (371° C). Since the mass of the mold was approximately 190 times that of the babbitt and the mold material's heat capacity was over 2.5 times that of the babbitt, the cooling and solidification was controlled by the mold preheat temperature. The temperatures used for preheating were chosen to cover the range of recommended mold and babbitt temperatures, as found in the literature.[1,3,4] Preheating was done in an electric muffle furnace, with the temperature measured by a type K thermocouple on the mold surface. The temperature of the mold assembly at the time of removal from the furnace was recorded; the babbitt was cast in the mold within 10 seconds after the mold assembly was removed from the furnace.

RESULTS AND DISCUSSION

The results of the tensile tests performed on the babbitt-bonded assemblies are given in figures 2 and 3, including both the average and range of breaking strengths for each group of four specimens cast by the method and at the temperature indicated.

The results for method I, the standard method, using a mold preheat temperature of 620° F (327° C) and 700° F (371° C) show that the breaking strength varied greatly in the eight specimens tested. Only one of the specimens, with a breaking stress of 16,200 psi (112 MPa) failed in the babbitt rather than at the babbitt steel bond. The other seven specimens failed at the bond with breaking strength as low as 2,600 psi (17.9 MPa). All of the seven specimens with bond failures had oxides covering 30% to 90% of the fracture surface. Theoretically, the oxide layer on the tinned surface should float to the surface of the babbitt and, therefore, not degrade the bond integrity. Method I was modified to alleviate the problem of the tenacious oxide film. Pouring a small amount of flux solution into the mold prior to casting the babbitt allowed the flux to float on the babbitt and remove the oxide as the level of the babbitt rose in the mold. This method, IA, gave excellent results, as seen in figure 2, where all of the 20 specimens tested failed in the babbitt. The average breaking strength of all the specimens was 13,500 psi (93 MPa). Hence, the bond strength must have been higher than the breaking strength. Although this method gave good results, the size of the tin bath necessary to hold a large bearing shell makes it impractical for shipboard use.

Method II was the result of a survey of procedures used on four tenders (AD 19, AD 26, AD 38, and AS 36). The only surface conditioning used was acetone degreasing and sanding. The blanks were tinned with an oxy-acetylene torch adjusted to give a reducing flame. Torch tinning does not require a tin bath or any floor space for permanent equipment. The results for eight specimens done by method II are shown in figure 2. The failures always occurred in the bond. The series performed at a mold of 670° F (354° C) contained some trapped oxide on all of the fractures, and the average breaking strength was 23% to 46% lower than for method IA. To remove the trapped oxides during casting, method II was also modified to include the additional step of pouring flux into the mold prior to casting. The results for the modified method, IIA, are shown in figure 2. The average breaking strength of method IIA was higher than method II but lower than method IA. Of the 20 specimens tested, four failed in the babbitt, and the remainder had from 10% to 50% of their fracture in the babbitt. The fracture surfaces indicated that the bond strength approximated the strength of the babbitt.

Method III was investigated as a possible method of simplification which eliminated the tinning step entirely. Surface preparation was limited to degreasing with acetone and sanding. In all the tests, flux was poured into the mold just prior to casting. Although the average bond strength in some tests of method III approach that of method IA, all of the specimens prepared by method III failed at the bond. This may have been due to a brittle, copper-rich phase of babbitt forming on the steel surface when a tin layer is not present. This difference in phase distribution may be noted in comparing figures 4 and 5, which are microprobe scan photographs of the distribution of copper at the interface between the steel and the babbitt.

Method IIIA was performed to determine the effect of an oil residue on the steel surface during preheating. After the steel blanks were degreased and sanded, they were dipped in machine oil and then placed in the stainless steel fixture. Further preparation was as for the other specimens prepared by method III. The specimens were cast with the mold preheated to 650° F and the average breaking strength was reduced 16% from the average of the eight specimens prepared by method III at 650° F. The range of breaking stresses was much greater with method IIIA. All four specimens failed at the bond, and three of the four had trapped oil residue on the fracture surface.

Method IV utilized a nickel-plating process to replace the tinning process. A nickel surface was electrochemically applied to the degreased and sanded steel surface with a portable brush plating apparatus.[3] The results for the specimens prepared by this method, figure 3, showed the procedure to be less effective than IA, IIA, and III. The breaking strengths were from 9% to 57% lower than 1A, and all of the 16 specimens tested failed at the babbitt-to-nickel bond.

Method VA was used to investigate the rebabbitting of specimens prepared by method IA which were previously prepared and tested. The babbitt was melted off the steel blanks, and new babbitt was cast to the same steel blanks with no other surface preparation. Method VB was similar to VA, but the steel blanks had been prepared by method III. The reduction of average breaking strength varied from 22% to 77% of the strength of the original value. All of the 24 specimens rebabbitted and tested failed at the steel-babbitt interface.

CONCLUSIONS

In comparing the results of the five different methods of casting babbitt, several conclusions may be drawn:

- The best method was the standard (tin-bath) method.

- The deleterious effect of oxides on the tinned surfaces can be eliminated through use of flux just prior to the babbitt casting.

- The tinning of a steel surface is required for a bond strength greater than that of the babbitt metal.

- Nickel plating is not a worthwhile alternative to tinning. Although a clean metal surface without a tin layer may have a high breaking strength, the bond will usually be weaker than the babbitt itself.

RECOMMENDATION

Aboard Navy tenders and repair ships where the torch tinning must be used, it is recommended that procedures for these ships be specially documented and include the step of applying flux just prior to casting the babbitt, the procedures described under method IIA of this report.

TECHNICAL REFERENCES

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2 - "Bearing Babbitting Procedures," NAVSHIPS 250-644-2, Bureau of Ships, Navy Dept, Washington, D. C. (May 1961)

3 - "The Dalic Process-An Advanced Engineered System of Selective Brush Plating," Sifco Matachemical, Division of Sifco Industries Inc., Independence, Ohio (1968)

4 - Bassett, H. N., Bearing Metals and Alloys, Butler and Tanner Ltd., London, U. K. (1937)

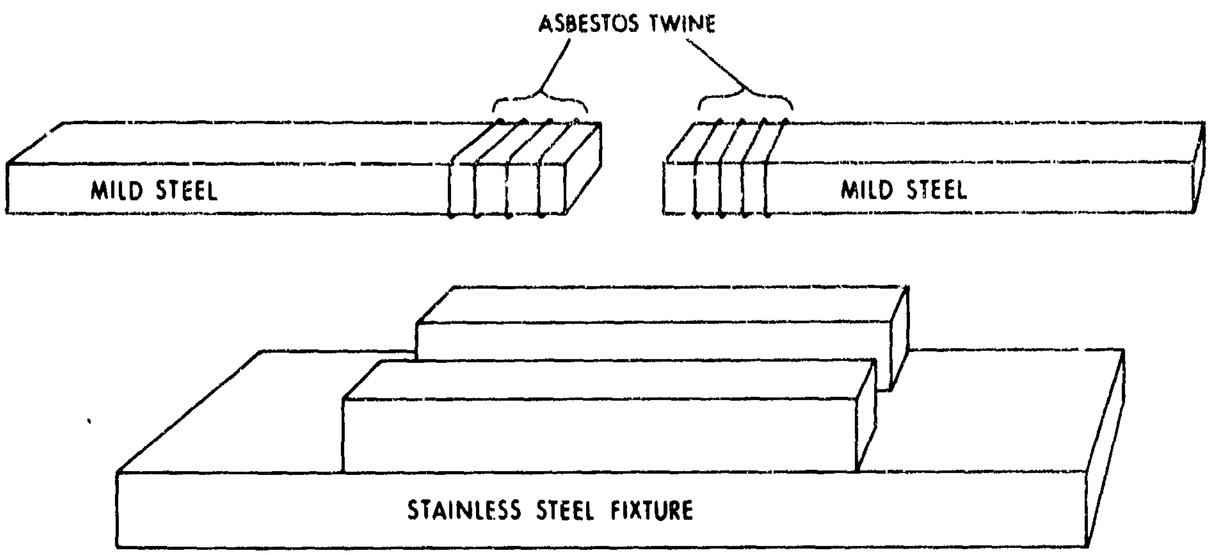
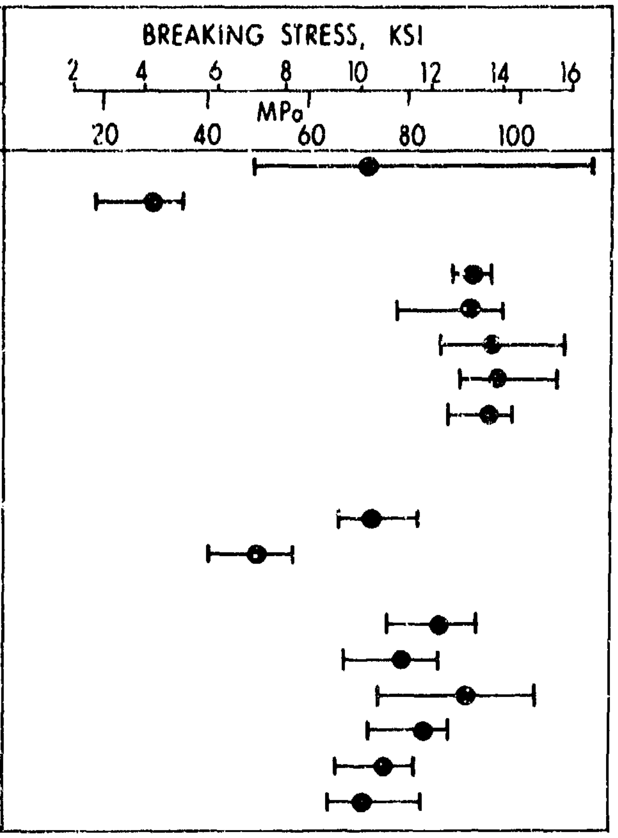


Figure 1
Stainless Steel Fixture and Mild Steel Blanks Assembly
of which Forms the Mold and for
Casting the Babbitt

METHOD	MOLD TEMPERATURE °F	MOLD TEMPERATURE °C
I	620	327
I	700	371
IA	580	304
IA	600	316
IA	650	343
IA	660	349
IA	700	371
II	560	293
II	670	354
IIA	550	288
IIA	614	329
IIA	650	343
IIA	700	371
IIA	750	399
IIA	950	510



RANGE OF BREAKING STRESSES
AVERAGE OF FOUR TESTS

Figure 2
Results of Tensile Specimen Tests Prepared by
Methods I and II

76-0037

METHOD	MOLD TEMPERATURE °F	MOLD TEMPERATURE °C
III	480	249
III	570	299
III	640	338
III	650	343
III	650	343
III	750	399
IIIA	650	343
IV	500	260
IV	650	343
IV	660	349
IV	770	410
VA	550	288
VA	650	343
VA	650	343
VA	700	371
VB	600	316
VB	650	343

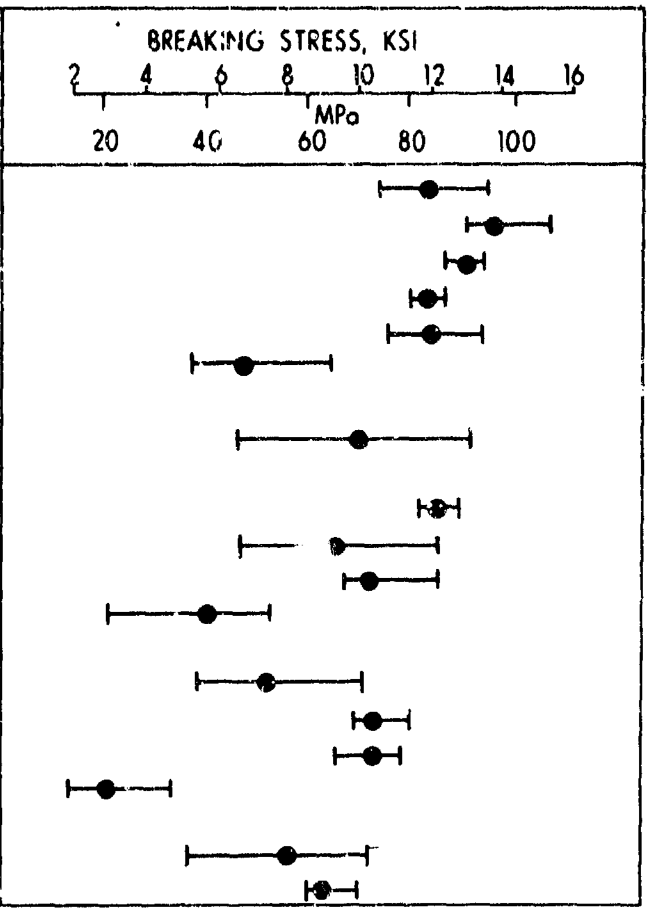


Figure 3
Results of Tensile Specimen Tests Prepared by
Methods III, IV, and V

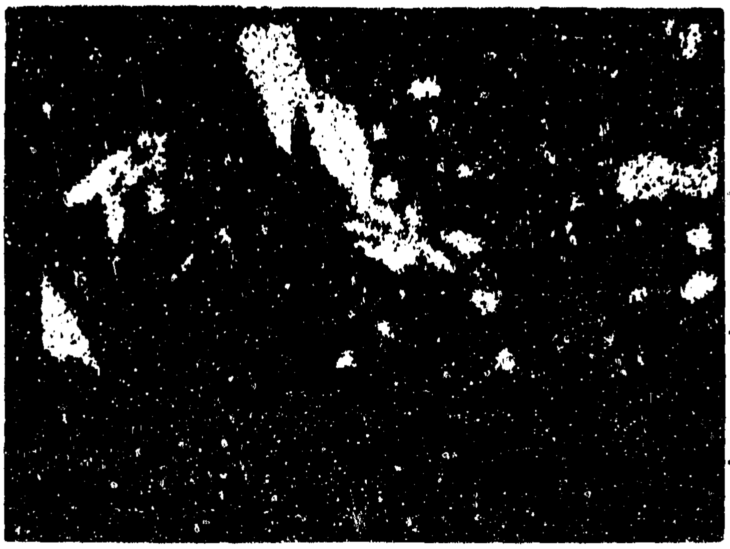


Figure 4
Microprobe Scan Photograph of the Babbitt-to-Steel Interface of a Tinned Specimen Showing the Distribution of Copper (white dots), 500X

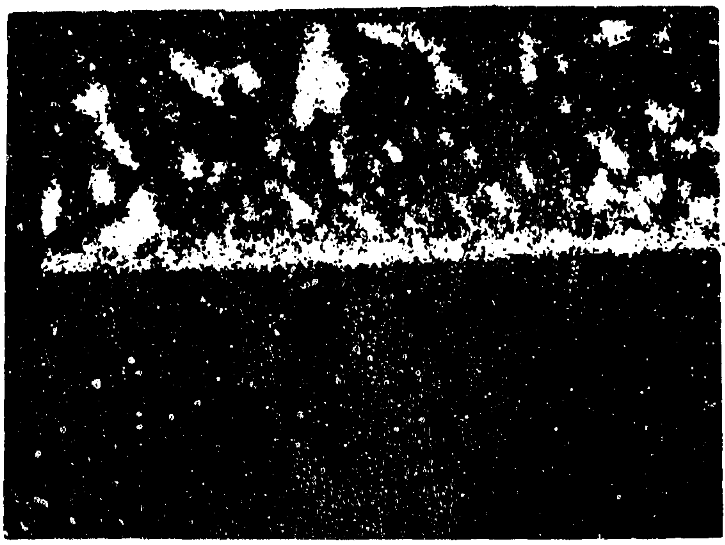


Figure 5
Microprobe Scan Photograph of the Babbitt-to-Steel Interface of an Untinned Specimen Showing the Concentration of Copper at the Interface (white dots), 500X

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